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and

Office of Energy, Bureau for Science and Technology
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**ENERGY FROM
SAWMILL WASTES
IN HONDURAS**

INDUSTRY OVERVIEW

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Abbreviations

| | |
|---------------|---|
| BEST Project | Biomass Energy Systems & Technology Project |
| BTU/lb | British Thermal Units per pound |
| CARES Project | Central American Rural Electrification Support Project |
| COHDEFOR | Corporación Hondureña Desarrollo Forestal |
| ENEE | Empresa Nacional de Energía Eléctrica |
| FAO | Food and Agriculture Organization (of the United Nations) |
| gal. | U.S. gallon |
| GDP | gross domestic product |
| IRR | internal rate of return |
| kW | kilowatt |
| kW/Mbf | kilowatts per million board feet |
| kWh | kilowatt-hours |
| kWh/yr | kilowatt-hours per year |
| Lps. | Lempiras |
| Mbf | million board feet |
| Mbf/yr | million board feet per year |
| NPV | net present value |
| PDF | Forestry Development Project |
| psig | pounds per square inch/gauge |
| USAID | United States Agency for International Development |

Executive Summary

This study presents a technical and financial appraisal of wood energy cogeneration in Honduras. The results indicate three important points:

- o There are no significant technical constraints to the use of wood energy systems in Honduras.
- o Investments in wood energy systems in Honduras would meet or exceed reasonable investment performance criteria. Such investments at larger sawmills and sawmills that have markets for off-site sales of surplus energy products would be especially attractive.
- o Waste-wood-fired energy systems could significantly increase the national energy supply in Honduras, while substantially reducing waste disposal problems.

Most sawmills in Honduras currently derive their energy requirements from imported petroleum products. At the same time they generate and discard large quantities of energy-rich wood wastes, a practice which entails both economic and environmental costs. These wastes could supply all the sawmills' energy requirements, plus have the following benefits:

- | | |
|--|---|
| o <i>Incorporate Renewable Energy</i> | o <i>Contribute to National Energy Independence</i> |
| o <i>Promote Sustainable Forest Management</i> | o <i>Increase Operating Margins</i> |
| o <i>Increase Use of Local Resources</i> | o <i>Increase Employment</i> |
| o <i>Increase Environmental Benefits</i> | o <i>Enhance Rural Development</i> |

Industry-wide use of wood-energy systems designed to provide energy for sawmill operations alone could replace nearly 10 million kilowatt-hours per year of electricity that is currently generated primarily from diesel fuel. Use of higher efficiency wood-energy systems could provide, in addition to the energy required to run the sawmills themselves, significant quantities of surplus energy products in the forms of electricity, steam, or solid fuels.

The amount of electricity available for off-site sales from the large and small representative sawmills, using the energy-efficient technologies described in this study, would be approximately 3,277,000 kilowatt-hours for the former and 1,005,000 kilowatt-hours per year for the latter. This equates to approximately 455 kilowatts and 140 kilowatts, respectively, of *constant* power generation levels over a 24-hour period for 300 days per year. Power generation levels for peak

and off-peak periods can be easily calculated depending on the demand characteristics of the grid. Equipment costs for systems designed for peak/off-peak variations would be higher than those designed for constant power output; such additional costs, however, may be more than offset by increased revenues typically associated with higher rates during peak periods. If all of the available wastes were utilized in systems incorporating the higher efficiency design, approximately 53.7 million kilowatt-hours of electricity could be produced for sale to national, local, or micro-grids.

Honduran forests can and should provide commercial wood products on a sustained basis. The amount of wood processed varies with the season and year, but there are more than adequate quantities of wastes to supply virtually all of the energy requirements of Honduran sawmills, as well as a significant amount of export energy products in the forms of electricity, steam, or solid fuels. Because nearly all wood wastes are produced in rural areas, waste-wood energy systems could provide rural employment opportunities and stimulate rural development. In addition, forest residues have enormous energy potential. Their use as a fuel could create additional rural employment opportunities and encourage sustainable forestry management practices. The potential benefits from the use of forest residues have not been incorporated into this study, but the concept should be further explored.

The positive environmental impacts from utilization of wood-energy systems in Honduras would be significant. Current waste management practices such as dumping or open-pit burning would be eliminated. And as long as forests are managed on a sustainable basis, there would be no net contribution to global atmospheric warming. Current Honduran plans anticipate the implementation of a regulatory system designed to ensure sustainable harvests in areas of commercial wood production. The sponsors of this study assume that this effort will continue in the future, and that the emergence of a market for energy products will enhance the attractiveness of responsible forest management.

There are no significant technical barriers to the installation of wood-fired energy systems in Honduras. The technology that appears to be most practical for these applications is the utilization of fire-tube type boilers and single-stage steam turbine generators in systems that have been designed to require no additional fuel preparation and operate without sophisticated auxiliaries and control systems. Several sawmills in Honduras already use such technology.

The use of waste-wood energy systems for kiln drying would represent a significant additional benefit to Honduran sawmills. The case-study systems discussed herein provide enough steam and electricity to dry 25 percent of the mills' primary lumber production. It has been suggested that for some Honduran sawmills, as much as 70 percent of the lumber could be dried with significant benefit to the mills. Investigations of this issue should be undertaken in all site-specific feasibility studies.

Since wood wastes are abundant at sawmills, the cost of operating waste-wood-fired energy systems are much less than the cost of providing energy with diesel-fired engines. In order for these systems to be economically feasible, however, the operational savings have to be sufficient to justify the capital cost of the installations.

To assess the financial viability of sawmill-based wood energy systems in Honduras, a series of preliminary financial analyses were made on representative, or case-study, system configurations. The representative systems were selected in order to analyze the influence of key variables on the generic economic feasibility of wood-energy system investments. The variables studied include sawmill size (measured in terms of annual lumber production), type of technology (degree of conversion efficiency), and off-site sales of surplus power vs. sawmill energy self-sufficiency only. For the purposes of preliminary analysis, a set of conservative base-case financial assumptions were adopted, and capital cost estimates have assumed that the major pieces of equipment needed would be purchased at U.S. price levels for new equipment.

Using the conservative base-case assumptions, the mill energy self-sufficiency systems alone meet or exceed acceptable financial performance levels. When the additional benefits available from self-sufficiency energy systems are factored in, such as the ability to run kiln driers and to do more secondary product manufacturing, these types of systems look more attractive in the context of the entire sawmill operation. However, self-sufficient systems generally fail to provide complete disposal of sawmill wastes.

The availability or development of markets for off-site sales of surplus energy products greatly enhances the economic viability of waste-wood energy system investments and provides a more complete solution to the waste disposal problems of the host sawmills. With access to unlimited markets for off-site sales (such as the national electric grid), higher levels of investment to achieve greater conversion efficiencies of the waste-wood energy systems can be justified (at least within the range of technologies considered in this study). As is typical of investments in systems of the kind considered in this study, larger systems realize significant economies of scale in comparison with smaller systems.

For those sawmills that do not have access to the national grid, densification of excess wastes to produce wood fuel that could be sold in local markets may be an attractive option for disposal of waste not required for on-site energy needs. A densification system currently being installed in Honduras is expected to provide information for evaluating this option in future site-specific studies elsewhere in the country.

The returns on system investments range from approximately 75% IRR for large mills (*energy-efficient, grid-connected* design) to 17% IRR for small mills (*low-capital, self-sufficient* design), with simple payback periods ranging from 3.4 to 6.2 years, respectively. Sensitivity analyses show the investments to be more sensitive to capital costs than to operating costs, and sensitive to several national economic variables, including overall inflation rates, currency devaluation rates (relative to the US dollar), and inflation in fuel prices.

This study reveals the promising technical and economic feasibility of wood energy systems in Honduras. Follow-up studies will include a detailed investigation of the feasibility of investing in a wood energy system at at least two specific sites.

1. Energy Use and the Wood-Products Industry in Honduras

The Honduran wood-products industry is a major sector of the national economy, and a major earner of foreign exchange for the country. Most sawmills in Honduras use imported petroleum products while at the same time generating large quantities of energy-rich wood wastes, a practice which entails both economic and environmental costs. These wastes could provide the sawmills with all of their energy requirements, reduce the sawmill's burden on the environment, and provide surplus energy in the forms of electricity, process steam, or solid fuels for the national economy. In order to realize this potential, it is necessary to attract investment capital to install waste-wood fired energy systems at the individual sawmills in Honduras.

1.1 Energy Production and Use at Sawmills in Honduras

The primary form of energy used by existing sawmills in Honduras is electricity, which is usually generated on-site with diesel engine-driven generators or, less commonly, purchased from the national electric utility company, Empresa Nacional de Energía Eléctrica (ENEE). At least two Honduran sawmills are currently generating their own electricity from wood wastes. These mills, located within environments similar to those considered in this study, exemplify the fact that on-site power generating systems can be successfully operated in Honduras.

Most of the electricity consumed by existing sawmills is used by the electric motor drives on saws and other items of manufacturing equipment. The sawmills are generally designed to minimize electrical requirements by substituting manpower for electrical power whenever possible.

Sawmills in Honduras typically operate with a single, eight to ten hour shift per day for five or five-and-one-half days per week. Some of the mills that use diesel generators shut down their generators when the mill is not operating, while others will run the generators at low power levels during non-operating hours to supply electricity for domestic and other light-duty applications.

The powerhouse in a sawmill producing on-site power typically contains two or three engine-generator sets, one of which is a stand-by unit, and a diesel-fuel storage tank sized to hold a one- or two-week supply of fuel. Typical fuel requirements for the sawmills covered by this study

vary between 500 and 1200 gallons per week, depending on mill capacity and generator utilization during non-operating hours.

The domestic price of diesel fuel in Honduras was 3.99 Lempira (Lps.) per US gallon (~US \$0.75/gal.) when the study team was in country (September 1990). Although this had been the prevailing price for some time, due to the recent international political crisis in the Persian Gulf international oil prices have risen drastically in recent months, and domestic retail fuel prices in Honduras jumped approximately 50% in October 1990.

The national electricity grid in Honduras covers only a limited area of the country. Sawmills that have access to the grid have the option of purchasing electrical power from ENEC. The current industrial electric tariff rates in Honduras (as of September 1, 1990) are based on two components: a monthly demand charge of Lps. 20.00 per kilowatt (kW), based on 85% of the monthly maximum demand, and an energy charge of Lps. 0.18 per kilowatt-hour (kWh). Almost all of ENEC's electrical production capacity is in the form of hydroelectricity, so recent oil-market disruptions should not have a drastic impact on the domestic cost of electricity in Honduras.

The following table indicates the estimated annual cost of purchased energy in the forms of diesel fuel or utility electricity for large (~9 million boardfeet per year {Mbf/yr}) and small (~3 Mbf/yr) sawmills in the size range covered by this study. Costs shown for diesel do not include estimates for depreciation and equipment operations and maintenance. Costs indicated for utility electricity are for power purchases only, and do not include costs of transformers and other interconnection equipment. Electricity costs also assume the availability of a high voltage utility interconnection. If utility lines in the vicinity of the sawmill are medium voltage lines, the cost of purchased power is approximately 25% higher than indicated.

| LARGE SITE | SMALL SITE | |
|---------------------|--------------|--------------|
| Diesel Fuel | Lps. 420,000 | Lps. 175,000 |
| Utility Electricity | Lps. 120,000 | Lps. 70,000 |

These estimates are based on information obtained from inspection of representative operations and are intended only to indicate an industry average. Energy costs at a particular location may vary from the estimated cost. All costs are based on March 1991 prices. Maintenance and depreciation costs vary greatly, but are a major component of total energy costs.

In addition to electricity, a few Honduran mills use thermal energy (steam) for kiln drying of lumber. Recent increases in the demand for kiln-dried products in Honduras' traditional lumber markets indicate a need to consider additional thermal energy needs at Honduran sawmills, which are also considered in this study (see §3.2.1).

1.2 Sawmill Waste Production and Disposal

Sawmills produce large amounts of wood wastes during the routine production of lumber and other products from saw logs. Information obtained from various sawmill operations in

Honduras indicates that the total waste volume will vary between 47 and 52 percent¹ of the incoming log volume. The actual rate of waste generation at a given site depends on the efficiency of the sawmill operation and the degree of secondary product recovery at the mill. For the purposes of this study, it was assumed that the overall industry average production rate is 47% primary product (lumber) recovery and 10% secondary product recovery. Thus, *the average amount of wastes resulting from milling operations is approximately 43% of the incoming log volume; this amount, plus the 7% represented by bark, equals a total of 50% of the incoming log volume, which is the amount used for calculations in this study.* Waste volumes and moisture contents will likely vary from mill to mill, and must be considered in any site-specific evaluations.

The current waste-wood disposal method at sawmills in Honduras is to dump the wastes in piles, which are left to smolder and burn on a continuous basis. Most sawmills dump and/or burn their wastes on the periphery of the sawmill site, often near river banks, while some mills haul the wastes away from the site and burn them elsewhere. In either case, these disposal practices lead to the production of acrid ground-level smoke, and serious soil and water contamination. Sawmill waste-wood disposal is a major environmental problem in rural Honduras.

While there is a limited market for certain sawmill wastes, such as shavings to be used as litter for chicken production facilities, it is considered insignificant for the purposes of this study. It should also be noted that some sawmill wastes (typically slabs or off-cuts) are removed from the site by some of the laborers or local villagers for domestic purposes. Although this could be a significant social issue on a site-specific basis, the total quantity of wastes removed for such purposes are considered insignificant for the purposes of this study. Further, the costs associated with existing waste disposal practices (e.g., incinerators or hauling costs to remote dumping sites) have not been considered in this study.

Annex 1 shows a list of the primary sawmills in Honduras, including their annual production of dimension lumber and their calculated annual production (@ 50% of log volume) of wood wastes for 1989, the most recent production year for which data is available. The table also shows each sawmill's own highest annual production data between 1984 and 1989.

1.3 Honduran Energy Use in Context

Honduras has a land area of 112,088 square kilometers and approximately 5 million people. The per capita GDP of Honduras in 1985 was about US\$ 730, one of the lowest in Latin America. Real growth of GDP in the 1970s was a very low 1% per year. In the early 1980s, it was a minus 9%, but recovered slightly in the late 1980s. In 1987, less than 1% of rural workers earned more than US\$ 35 per month. (DESFIL 1989)

¹ These figures include bark, which is approximately equal to 7% of the incoming log volume; this will not normally be included in COHDEFOR's mill log volumes since log and tree measurements are based on d.i.b. (diameter inside bark). The amount of waste wood generated during milling operations, exclusive of bark, varies between 40% and 45% of the incoming log volume.

Forest products and hydropower are the major indigenous energy resources in Honduras, with forests providing nearly 70% of current energy use (primarily as domestic fuelwood). Current electric power consumption is about 1,500 million kilowatt-hours per year, although with adequate production and distribution capacity the consumption potential is much greater. No commercial deposits of petroleum or coal have been discovered, and the limited deposits of peat that have been identified are of poor quality. Some possibility exists of useable geothermal power in Honduras, although this resource needs additional investigation. Petroleum makes up about 16% of total country imports (FAO, 1987).

The World Bank estimates that the Honduran population will grow at 3.7%, and that GDP will grow at 3% per year during 1986 - 1990, and 5.2% per year for 1991 - 1995. In 1995, electricity (primarily hydropower) is projected to provide 7% of total energy use, petroleum 29%, and biomass 64%. Fuelwood is expected to continue to provide the cheapest fuel for the household (60%) and industrial (14%) sectors. All transport fuel is expected to continue to be petroleum based (World Bank, 1980).

Approximately two-thirds of Honduras' electricity consumption is in the three major cities, Tegucigalpa, San Pedro Sula, and La Ceiba. Although the country has experienced an excess of electrical generation capacity since the El Cajón hydroplant began operations in 1985, Honduras' distribution system remains relatively undeveloped. Due to ENEE's existing financial burdens (resulting in part from its inability to export excess power to other countries because of the limited capacity of the Central American transmission system), future distribution and rural electrification plans are uncertain. Consequently, many rural areas remain without electricity for the foreseeable future. Further, increasing urban and industrial demands are projected to catch up with existing capacity within two to four years. Thus, the potential for excess electrical generation from sawmill wastes and forest residues could be a small but significant component of the country's overall energy picture -- either for remote, off-grid applications, or through interconnection with the national grid (ENEE, 1988).

1.4 Study Objectives and Follow-up Activities

This study assesses the potential of using waste-wood-fired energy systems within the wood-products industry in Honduras. Follow-up activities will investigate, in detail, investment opportunities at specific sites. The site-specific feasibility studies are expected to produce analyses and specifications that could be used to support investment decisions for wood-energy systems at the sites evaluated.

1.4.1 Potential benefits of wood-energy systems in Honduras

Technology exists and could be used routinely in Honduras to convert sawmill wastes and forestry wastes into useable energy. Substantial quantities of such potential fuel sources in

Honduras are being wasted, and the disposal of this material is contaminating the air, water, and soil. The use of wood-energy systems in Honduras could have benefits in the following areas:

- o **Renewable Energy.** Substitute local renewable energy for imported energy from non-renewable petroleum products.
- o **Sustainable Forest Management.** Provide incentives for sustainable forest management through adding value to sawmill wastes and forest residues that would have new value as fuel for wood-energy systems.
- o **Use of Local Resources.** Use Honduran land, labor, and currency to produce renewable energy instead of using scarce foreign exchange to purchase petroleum. Recent developments in the Middle East have caused a surge in petroleum prices, and there is little doubt that prices will continue to climb, even if actual shortages do not occur.
- o **Environment.** Reduce environmental degradation by reducing emissions of carbon monoxide and particulates and limiting the introduction of solid wastes into streams and rivers, drainage ways, or ground water. Reduce potential global warming through the use of renewable energy and completing the carbon cycle. *As long as forests are managed on a sustained basis --as is currently being planned by the COHDEFOR/AID PDF project-- there will be no net contribution to global atmospheric warming.*
- o **National Energy Independence.** Sell excess electricity to reduce planning, capital construction, and other costs (such as delays and environmental degradation) associated with petroleum-based, hydroelectric, and other generation and distribution facilities. Such sales in rural, off-grid areas would reduce costs of and delays in placing power in the homes and shops of users, particularly in small and remote villages where grid access is not imminent.
- o **Operating Margins.** Improve sawmill operating margins by reducing the costs of energy required for manufacturing operations (thereby contributing to the longevity of the Honduran forest industry) in addition to potential increases in revenues through off-site sales of energy products.
- o **Employment.** Installation operate wood-energy systems to create needed employment opportunities, particularly in rural areas.
- o **Rural Development.** Increase the availability of energy to rural populations to enhance rural development activities.

1.4.2 Case Study Approach

In order to assess the overall viability of investments in sawmill waste-wood energy systems in Honduras, the study team adopted a case-study approach. The case-study system configurations as defined below are intended to represent a cross section of the wood products industry, including considerations of both sawmill size and the possibilities for sales of surplus energy

production to off-site users. Sawmill size (i.e., production capacity) dictates the energy consumption requirements, as well as the amount of available wastes at a particular site.

Sawmills with lumber production capacities in excess of 1 million boardfeet per year (Mbf/yr) can produce all of their on-site energy requirements using wastes generated on-site and the lowest capital-cost technology considered in this study. More than three-quarters of the sawmills in Honduras, which produce more than 95% of the country's lumber output, are in this category. The case studies have been designed to represent this range.

Working with COHDEFOR and PDF staff, the study team defined two representative sawmill sites for the purposes of the case studies: a large volume site (8 - 10 Mbf/yr) and a small volume site (2 - 4 Mbf/yr). In order to ensure the accuracy of the site-specific information used in the evaluation, it was decided that the system designs used in this overview assessment should be based on the characteristics of sawmills actually visited by the study team. The large sawmill site data is based on the San Jose sawmill in Olancho (8.9 Mbf/yr, 1989). The small sawmill site data is based on the Teupasenti sawmill in El Paraiso (3.0 Mbf/yr, 1989). Although both data sets are based on actual sites, the use of the data in this study is for representational purposes only. Further, many of the calculations in this report are based on certain generalized assumptions that need to be ascertained and verified on a case-by-case basis prior to final conclusions and subsequent investment decisions for specific sites.

For each of the two representative sawmill sizes, three waste-wood energy system configurations are analyzed:

- o Low Capital Cost, Mill Energy Self-Sufficiency
- o Low Capital Cost, Off-Site Energy Sales (including mill energy self-sufficiency)
- o Energy Efficient Design, Off-Site Energy Sales (including mill energy self-sufficiency)

The three types of system configurations defined in this overview represent two different approaches to sawmill energy production and waste management, with two variations for the second type of approach. The first approach, which is referred to as *energy self-sufficiency*, involves installing an energy system that is designed to provide all of the host mill's site energy requirements, but no surplus energy products for sale to off-site users. Except for the smallest sawmills under consideration in this study, the energy self-sufficiency approach will not provide sawmills with a complete solution to their waste disposal problem, since the wastes produced exceed the amount needed for energy generation. Using the energy self-sufficiency approach, mill owners will choose the least-cost (and least-efficient) energy conversion equipment possible, since the fuel is free and abundant and the available benefits of the investment (avoided purchase of diesel fuel) are fixed.

The second approach, which is referred to as *off-site energy sales*, involves designing a system for full utilization of the available waste supply, with the intention of having energy self-

sufficiency plus having or developing export markets for the surplus energy production capacity of the system. There are a number of possible export markets that may be used, including:

- o For sawmills that have access to the national electricity distribution grid, excess electricity production can be sold to ENEE, the national electric utility company. ENEE's charter allows the utility to purchase power from independent sources, and the utility has expressed an interest in such opportunities.
- o For sawmills that do not have access to the national grid, it would be necessary to identify other markets for their surplus energy production capacity. Several possibilities exist, including forming rural electric cooperatives for nearby towns², encouraging the growth of rural or cottage industries, or converting excess wastes into densified fuels or charcoal for domestic heating and cooking or energy-intensive industrial markets³.

For the purposes of this industry overview study, we have modeled all off-site energy sales as sales of surplus electricity to the national grid. Also, the above discussion refers exclusively to production and sales of *electrical* power, although production and off-site sales of *thermal* energy or solid fuels is possible (refer to §3.2.1 and §4.2).

The technical and engineering details of these system configurations are described in Section 3 of this report. Section 4 describes the financial feasibility analyses of the six case-study system configurations. Conclusions and recommendations are presented in Section 5.

1.4.3 Study Participants

This study has been undertaken by Winrock International's Biomass Energy Systems & Technology (BEST) Project, in cooperation with:

- o the Corporación Hondureña Desarrollo Forestal (COHDEFOR), through it's Proyecto Desarrollo Forestal (PDF) project
- o the United States Agency for International Development in Washington, D.C. (AID/W) and the AID mission in Honduras (USAID/Honduras)
- o Empresa Nacional de Energía Eléctrica (ENEE), Honduras' national electrical utility agency

²The Central American Rural Electrification (CARES) Project is a USAID/ROCAP rural electrification program in Central America. The CARES project assists in the formation of rural electric cooperatives, and has recently completed a prefeasibility study for the creation of rural electric cooperatives in Honduras.

³The YODECO sawmill in Yoro intends to install sawmill waste densification equipment, in order to test the technology and begin identifying markets for the densified fuel. Other Honduran sawmills should monitor the results of this activity, as densification may prove to be a substantial market for certain mills within economic access to potential markets for such products.

- o the USDA Forest Service, which provides technical assistance to the COHDEFOR PDF project, through funding from USAID/Honduras

The BEST project is a cooperative agreement between Winrock International Institute for Agricultural Development and the AID/W Office of Energy, Bureau of Science and Technology. The BEST project, based in Arlington, Virginia, works with USAID missions, private companies, and organizations in developing countries to expand the use of biomass energy systems.

The study team for this industry overview consisted of:

- o Dr. C. B. Briscoe, Forestry Specialist and Team Leader for this overview study. Dr. Briscoe is a self-employed consultant based in Turrialba, Costa Rica.
- o Kelton Grubbs, Engineer/Cogeneration Specialist. Mr. Grubbs is President of Thermal Systems Engineering, Inc., based in Hot Springs, Arkansas.
- o Dr. Gregory Morris, Economist/Financial Analyst. Dr. Morris is a principal with Future Resources Associates, Inc., based in Berkeley, California.
- o Jim Wimberly, the project manager for this study. Mr. Wimberly is a Program Officer with Winrock International's BEST Project.

We would like to express our sincere appreciation to the following individuals for their support and assistance with this study:

- o Ing. Mateo Molina, Director, COHDEFOR PDF project
- o Ing. Danilo Escoto, Chief of the Technical Assistance Unit to the Industry, COHDEFOR PDF project
- o Lic. Mauricio Mossi, Chief - Planning Department, ENEE
- o Dr. Rafael Rosario, Director - Natural Resources Department, USAID/Honduras
- o Dr. John Warren, Project Officer, USAID/Honduras
- o Ing. Ramon Alvarez, Forestry Specialist and Assistant Project Officer, USAID/Honduras
- o Mr. John White, Advisory Team Leader, PDF Project, USDA Forest Service
- o Mr. Doyle Romans, Industrial Forestry Advisor, PDF Project, USDA Forest Service

2. Forestry & Environmental Considerations

2.1 Forest Resources & Utilization

Forests were once the natural cover for almost all of the land area of Honduras but now occupy less than 60% of the country, about 5 million hectares (ha). Of these, about 2.6 million ha are hardwood forests and 2.4 million are pine. Approximately 80% of existing forested lands are suitable for production forests; 8% is suited for intensive agriculture. The remaining 12% is best suited for natural areas and carefully managed watersheds. The energy contribution of the forests is proportionately greater than the percentage of land they occupy: 68% of all energy used and 86% of primary domestic energy production is from forests (fuelwood) (DESFIL, 1989).

Lumber production from both pine and hardwoods has been one of Honduras' most important industries since the 19th century. Although hardwoods (including the well-known Honduran mahogany) once represented a significant portion of the country's lumber production, pine is now the primary lumber for both domestic and export markets. Active reforestation activities are almost non-existent, so the forest industry relies heavily on the high natural regeneration rate of Honduran pine. The average maturation age for commercially-harvested pine in Honduras is approximately thirty years, and many areas in the country are experiencing their third harvest. Table 2.1 presents data that show trends in forest areas in Honduras over the last twenty-two years (Groothausen, 1989).

Table 2.1
Estimated historical forest area

| Forest Type | Inventory | | Change, 22 yrs | | |
|-------------------|------------------|------------------|----------------|------------|----------------|
| | FAO 1964 | COHDEFOR 86 | ha | % | ha/yr |
| Pine (commercial) | 1,936,500 | 1,004,500 | -932m | -48 | -42,364 |
| Pine (immature) | <u>802,300</u> | <u>1,392,300</u> | <u>590m</u> | <u>74</u> | <u>26,814</u> |
| Subtotal | 2,738,800 | 2,396,700 | -342m | 12 | -15,550 |
| Hardwoods | <u>4,072,200</u> | <u>2,654,300</u> | <u>-1,418m</u> | <u>-35</u> | <u>-64,450</u> |
| Total forests | 6,811,000 | 5,051,000 | -1,760m | -26 | -80,000 |

Although deforestation is estimated at 80,000 ha per year (about 20% pines) and there has been little coordinated and sustained management of forest resources, basic government policy in Honduras has long recognized the importance of forests for soil and water conservation and as a source of valuable products. COHDEFOR's current PDF project⁴ is attempting to reverse these negative trends by introducing and supporting sustainable forest management practices in Honduras.

Current plans are again anticipating control of forest harvest and informal colonization, as well as promotion of natural regeneration and thinnings as needed. If carried out, such management will permit perpetual harvest near the present level, as well as protection of non-commercial reserves and major watersheds.

Without sustained management, however, Honduras will be barely self-sufficient in forest products within about 15 years, and wood importation will be necessary soon after. Thus, until satisfactory forest management plans are effectively implemented, any plans for wood waste utilization should maintain a time horizon of less than 15 years. Effective forest utilization with viable industries providing community benefits will help to achieve sustained management.

2.2 Forest Residues as a Potential Fuel Source

In addition to sawmill wastes, forest residues such as thinnings and harvesting wastes could be transported to the mill and used to generate additional energy. Forest residue removal could have considerable beneficial effects on sustainable forest management by adding value to otherwise valueless residues, offsetting the costs of thinning operations (desirable from a silvicultural perspective), and reducing potential wildfire damage, a serious problem in Honduras. Additionally, the collection, removal, and transportation of such residues could create significant additional rural employment. Although the additional potential fuel supplies represented by such residues in Honduras have not been considered in this study, such consideration is encouraged.

2.3 Applicable Forest Policies

Land ownership distribution in Honduras is unequal and remains a social problem despite continuing efforts toward agrarian reform. At the time of the last census, 64% of the farms were 5 ha or less in size; however, these same farms occupied only 9% of the land. Apparently, lack of clear land titles is the single greatest obstacle to responsible land management. Much of the

⁴The purpose of the Proyecto Desarrollo de Forestal project is to improve the management and sustainable productivity of commercial pine forests and the efficiency of industrial conversion and marketing of wood products; the PDF project is financially supported by USAID and receives technical assistance from the USDA Forest Service.

land has two or more claimants, often including the government. Without clear title none of the claimants is willing to invest in good land management (FAO, 1987).

Recent laws and regulations mandate forest management, but economic limitations and questionable forest policies have prevented complete implementation of the plans prepared. Silviculture in particular has received cursory attention, apart from recent emphasis on fire control.

A major policy handicap to efficient forestry management in Honduras is maintaining a division between tree ownership and land ownership. Current policy entails allocating all trees to government ownership. This virtually ensures antagonism of landowners toward the presence of forests. Overgrazing and frequent forest fires are two of the obvious effects of such a policy, pan-tropically and in Honduras. The subject has been adequately covered in other reports and will not be considered further here (FAO, 1987; FAO, 1968; Tenore & Cosenza 1980).

2.4 Environmental Aspects

Current waste disposal practices in the Honduran sawmill industry are causing significant air and water pollution problems in and around the mill sites. Open burning of sawmill wastes in smoldering piles creates an almost constant presence of ground level smoke and haze. Water run-off from exposed piles of unburned and partially burned wood waste is contaminating nearby streams and impoundments. Ground water contamination may also result from leaching of tannic acids resulting from biological degradation of sawmill wastes.

Utilization of these residuals for energy production will reduce or eliminate, depending on the degree of utilization, the need for open burning and the piles of unburned waste. If only this benefit is considered, installation of wood-waste-to-energy systems will significantly reduce the environmental degradation caused by current practices.

In addition, burning of the residuals in a controlled manner will produce significantly fewer air contaminants than are generated by open burning. Also, displacement of the diesel fuel presently being used to generate power for many of these operations could eliminate the emission of 200 to 400 tons per year of carbon monoxide, nitrogen oxide, particulate and other contaminants from these sources.⁵

The proposed wood-energy conversion systems have the potential for a significant and beneficial impact on the Honduran environment, and the magnitude of this impact is in direct proportion to the degree of utilization of these systems.

2.5 Summary

⁵Based on emission factors for diesel powered industrial equipment presented in U.S. Environmental Protection Agency Publication, AP-42, Third edition.

The Honduran forest industry apparently has an adequate supply of harvestable timber for at least the next 10 to 15 years. Given the current and projected lumber production rates and the high percentage of log volume that becomes waste, there will be a large supply of sawmill wastes available in Honduras for energy generation during this period. The most obvious use for such energy is for sawmill self-sufficiency, but additional power available for off-site users should be considered to the extent feasible.

Forest residues have enormous energy potential. Using these residues as a fuel source would have several positive effects on sustainable forestry management practices and would create significant additional rural employment opportunities. Although such potential benefits have not been incorporated into this study, it is recommended that this concept be further explored.

Although Honduras is still experiencing some deforestation, certain activities, such as COHDEFOR's PDF project, are underway to try to reverse this trend by promoting sustainable forest management practices. The two policy steps considered most necessary for long-term sustainability are: (1) to clarify land ownership issues; and (2) to vest tree ownership in the landowner.

The use of waste-wood-to-energy systems would have a substantial positive environmental impact, particularly in rural areas, through reductions in air and water pollution.

3. Engineering Considerations

3.1 Technical Issues

The forest products industry has been using residuals as an energy source since it began producing manufactured wood products. In the early days, manufacturing wastes were the only source of power for many sawmills. Today, these wastes represent the most economical energy source for most forest products operations. Utilization of residuals not only provides a low cost source of energy, it also represents a convenient solution to an otherwise enormous waste disposal problem.

The long history of wood waste utilization has produced a wide variety in the design of available combustion systems. These systems range from the basic, manually fired, pile burning systems typical of early sawmills, to the highly sophisticated, automated systems found in modern forest products plants. Available combustion technology options include multi-stage combustors, suspension burners and gasifiers, as well as conventional grate and pile burning systems.

In addition to the options in the selection of combustion equipment, there are different types of boilers, prime movers, fuel handling systems and auxiliary systems that can be incorporated into a waste-wood energy system. Making proper selections from the available options is critical to the development of a system configuration that is reliable, economically viable, and compatible with available technical skills. The selection process involves consideration of site-specific factors such as residual characteristics and availability, water characteristics and availability, other types of process energy required, and required system capacity. Economic evaluation of trade-offs such as operating labor vs. cost of automation and system efficiency *and* reliability vs. installation and operating cost is also a critical part of the selection process.

Information presented in the following paragraphs is intended to provide a summary of the conditions and factors that were considered in the development of the conceptual design of the systems on which the case studies are based.

3.2 Existing Site Conditions

There are numerous site-specific conditions that will have to be considered in the design of an energy conversion system for a particular sawmill. However, the conditions considered in this study have been limited to those items that are representative of the Honduran sawmill industry,

and that could have an impact on the conceptual design of systems that might be utilized by this industry.

3.2.1 *Energy Requirements*

The electrical requirements of existing mill operations will vary significantly from location to location. The requirements depend on the type and degree of re-manufacturing done at the mill, as well as the rated production capacity of the mill. For the purposes of this study it was assumed that re-manufacturing requirements did not vary significantly for mills in the size range being investigated, and that the average electrical load could be determined as a function of the production capacity. Based on information obtained at two of the mills that were visited, it was determined that the average electrical load was approximately 12.8 kW/Mbf of annual production in a larger mill (9 Mbf/yr) and 29 kW/Mbf in a smaller mill (3 Mbf/yr). Electrical requirements at other locations have been determined with an equation that relates the magnitude of the specific electrical load (kW/Mbf) to the annual production. Obviously, this approach introduces the possibility of a significant error in the estimated load at any specific location. However, this error should average out when the industry as a whole is considered.

Very few mills in the size range addressed by this study are currently kiln drying any of their lumber production. Information obtained during the site visits indicates that kiln drying could have a significant impact on the value of the lumber produced at the various sawmills. The installation of waste-wood energy systems at the mills would facilitate the introduction of kiln drying systems, because properly sized waste-wood boilers can provide steam for kiln drying as well as for power generation, and the fuel for both applications is free.

Kiln drying of lumber is likely to become a major issue in the near future in Honduras as the primary export market for Honduran lumber, the European Common Market, is instituting new regulations that will require all lumber imported into Europe to be treated against insects. The two options for meeting the new regulations are either kiln drying or chemical treatment. Kiln drying of lumber is not only safer and more environmentally benign than chemical treatment, it also provides some substantial additional benefits to the mill operation, including:

- o Reduction in freight cost: kiln drying reduces the weight of the product by as much as one-third, with attendant savings in freight costs.
- o Increased product value: kiln drying may not have a major impact on the prices received for export lumber, but lumber sold domestically is valued approximately 25 percent higher when it is kiln dried.
- o Enhanced opportunity for on-site remanufacturing: kiln-dried dimension lumber can be further up-graded at the sawmill site by performing surfacing operations there. Surfacing provides several benefits to the mill: increased product value in both domestic and export markets; further decrease in freight cost by removal of up to 25 percent of the weight and volume of the dried, rough lumber; and surfacing also produces sawmill wastes that increases the amount of fuel available to the wood-energy system.

The benefits of kiln drying to any particular sawmill operation are site-specific, and are beyond the scope of this industry overview assessment. We have designed our case-study energy systems to provide enough steam and electricity for drying 25 percent of the mill's primary lumber production. For energy systems that provide for mill energy self-sufficiency only, this means a small increase in capital cost (in comparison to having *no* dry kiln) due to the need for a slightly larger boiler (5 to 10 percent larger) and turbine/generator. For systems producing power for off-site sales, there is no increase in capital cost, but such systems would produce slightly less export power, due to the steam and electric requirements of the dry kiln.

Our choice of the amount of lumber (25%) that is assumed to be kiln dried at a sawmill is somewhat arbitrary. We chose this value in part because it is large enough to illustrate its impact on the design of the energy systems, but small enough that it does not have a major impact on the economic value of such systems. It has been suggested that for some Honduran sawmills, as much as 70 percent of the lumber could be dried with significant benefit to the mill. Investigations of this issue should be undertaken in all site-specific feasibility studies. Components of this issue that will have to be considered include the costs of kiln drying and, possibly, surfacing (including capital and operating costs for each), as well as potentially enhanced revenues resulting from increased product values and reduced freight costs.

Depending on the efficiency of the power generation equipment, the dry kiln steam requirements will vary between 5% and 10% of the required boiler capacity. In other words, if dry kilns were not installed, the size of the boiler system could be reduced by 5% to 10% in those systems that were only generating power for on-site consumption, and the sale of exported electricity could be increased by the same amount in those systems that were producing power for external sales. Since it is not expected that a reduction of this magnitude in either the boiler capacity or exported power will be as beneficial as the increase in lumber value, the systems tentatively selected for evaluation in this study should be designed to produce the steam required for lumber drying. Also, the estimated average electrical load and the fuel requirement of these systems should be adjusted to reflect the impact of the lumber drying operation. Figure 3.1 indicates the variation in the estimated electrical power required for sawmill operation, dry kiln operation and powerhouse auxiliaries vs. rated mill capacity. While it is beyond the scope of this study to evaluate the economic impact of lumber drying on project viability, site-specific studies should address this issue in detail.

3.2.2 Residual Characteristics and Availability

The majority of the residuals produced by a typical sawmill operation are either green sawdust or solid pieces of slabs and edgings. At most Honduran sawmills, logs typically are not de-barked prior to sawing, and most of the bark is therefore disposed of with the slabs and edgings. As previously noted, few mills in the size range being investigated kiln dry their lumber. Therefore,

most of the waste volume is green and it has been assumed that the average moisture content is 45%, wet basis. For this overview study, we have assumed that the higher heating value of the residuals is 4,975 BTU/lb.

Information obtained from various sawmill operations indicates that the total residual volume, including bark, will vary between 47 and 52 percent of the incoming log volume depending on the efficiency of the sawmill operation and the degree of secondary product recovery. For the purposes of this study it was assumed that the overall industry average was approximately 50 percent residuals with 47 percent primary lumber recovery. The residual volumes and moisture contents may vary from mill to mill and any site-specific evaluations will require a more accurate assessment of residual characteristics.

3.2.3 *Water Characteristics and Availability*

All of the mill sites visited obtain water for their process requirements from nearby streams or from small surface impoundments. The quantity of water available varies significantly from site to site, and it is impossible to make a determination of water availability that is representative of the entire industry segment being studied. Therefore, in order to insure that the systems developed for evaluation in this study represent a design that can actually be installed, the systems are designed to minimize water consumption.

All of the streams had significant turbidity and color, and it can be assumed that some type of settling or filtration will be required if this water is to be treated in any type of ion-exchange unit. However, the sites visited that were operating boiler systems had no pre-treatment equipment and were achieving satisfactory results with some type of internal treatment. On this basis it can be assumed that new boiler systems, selected to operate at conditions similar to those of the existing boiler systems, can be operated without significant pre-treatment of the boiler make-up water.

While the assumptions described in the preceding paragraphs may be adequate for establishing representative system designs, they certainly are not suitable as the design basis for a system that would be installed at a particular location. Therefore, detailed site-specific studies should include an accurate assessment of the water availability and degree of pre-treatment required.

3.3 **Equipment Selection**

3.3.1 *Boilers*

The sawmill capacities considered in this study range from ~1 Mbf/yr to ~10 Mbf/yr, and the total boiler fuel produced will vary from 7,500 metric tons, wet basis, for the smaller mills to 25,000 metric tons or more for the larger mills. These fuel quantities indicate that the maximum boiler rating will be something less than 30,000 pounds per hour steam generation. In this size range, the most economical boiler selection is usually a fire-tube unit with a maximum operating pressure of less than 200 pounds per square inch/gauge (psig). Therefore, it was decided that the preliminary economic evaluations for this overview study should be based on systems designed around boilers of this type.

The other type of boiler that could be considered is a water tube design. This type of boiler provides a much wider range of operating conditions and configurations. However, in the size range considered in this study, water-tube boilers are considerably more expensive than fire-tube units, and the additional system efficiency that could be achieved with higher pressure steam conditions would have to justify the added cost. It should also be noted that mills in Honduras with existing boiler operations are utilizing boilers of the fire tube type, with operating pressures less than or equal to 200 psig.

3.3.2 *Combustion Systems*

The presence of random-sized solid wood pieces in the residual stream make it impossible to use combustion systems that incorporate automatic, precise control of the fuel feed rate. In fact, the only system that can use this material without further processing is a balanced, or negative draft furnace that has provisions for manually firing the larger pieces through the furnace doors. This type of furnace can also be equipped with a conveyor system that will deliver the sawdust and smaller pieces to the furnace through a feed chute in the roof or upper sidewall. The conveyor system can be equipped with an infeed hopper that will hold a fuel reserve and allow the operator to regulate the firing rate by starting and stopping the conveyor, as well as by adjusting the rate at which the larger pieces are fed to the furnace. While a combustion system of this type is not nearly as efficient as a more automated system, it is much less expensive and is consistent with the philosophy of substituting manpower for mechanical/electrical power when practical. Therefore, the conceptual designs of the systems evaluated in this study will include this manual-type combustion system. The site-specific studies may need to include an evaluation of the trade-off between operating efficiency and installation and/or operating cost to determine if economic viability can be improved by installing a more efficient combustion system.

3.3.3 *Prime Movers*

The choice of a prime mover for the generator is limited to either a steam engine or a single-stage steam turbine. Multi-stage steam turbines are not competitive in the size range being considered in this study, and are probably too sensitive to allow reliable operations for installations in the prevailing sawmill environment in Honduras.

Historically, steam engines frequently have been selected for applications of this type, and are utilized at the Honduran sawmills currently generating electricity from wood wastes. Steam engines have the advantage of a slightly higher operating efficiency and better off-load performance. However, steam engines have the disadvantage of being more expensive than single-stage turbines. Also, the exhaust from a steam engine is contaminated with lubricating oil and not suitable for reuse as boiler feedwater. Therefore, steam engines have the added disadvantage of higher make-up water requirements, which is not consistent with the perceived need to design these systems to conserve water.

3.3.4 *Condensing Equipment*

Having selected a single-stage turbine as the prime mover for the generator, a determination of the type of condensing equipment to be used for exhaust steam recovery must also be made. Either an air-cooled condenser or a water-cooled, surface condenser would be suitable for this service.

Air-cooled condensers are not usually economical for use with turbines operating at vacuum exhaust conditions. However, operation of the turbine at higher exhaust pressure has a

significant, detrimental impact on the overall system efficiency (i.e. the electrical output achieved from a given fuel quantity is significantly reduced). Preliminary investigations indicate that there is more than sufficient fuel available to produce the electricity required by the sawmill and powerhouse operations. Therefore, the only factor that can justify the added cost and water consumption of a water-cooled condenser is the value of excess electricity produced for off-site sales. It was decided that this study could establish a realistic comparison between the relatively low-cost systems designed to include an air-cooled condenser and the more expensive, energy efficient system designed with the turbine operating at a vacuum exhaust and including a water-cooled condenser. The low cost systems will be configured to operate with a turbine exhaust pressure sufficient to return condensate to the feedwater storage tank without using condensate pumps. This arrangement eliminates a significant amount of condensate handling equipment and results in a lower installed cost. Also, based on observations made at existing boiler operations in Honduras, it was decided that a vented, feedwater storage tank should be substituted for a deaerating feedwater heater. While this will probably result in increased water treatment cost it will reduce the installed cost and is consistent with current practice. This system configuration is referred to as the "low capital system," and the basic arrangement is shown schematically in Figure 3.2.

The installation of a water-cooled, surface condenser will also require the installation of condensate pumps, cooling water pumps, a cooling tower and condensate flow controls. This system is referred to as the "energy efficient system," and the basic arrangement is shown schematically in Figure 3.3.

There are no technical considerations that would favor either of these system configurations. Therefore, the selection of the most suitable system design should be based on an economic assessment of the value of the electrical output versus the installed and operating costs of the systems.

Preliminary, expected performance data have been developed for power generating systems incorporating both the "low capital" system configuration and the "energy efficient" system configuration installed at all sawmill locations in Honduras. These systems were sized for two different capacities: to produce all of the electrical power required by the sawmill, proposed dry kilns, and the powerhouse auxiliaries; and to use all available residuals for power generation with the excess being exported for off-site consumption. This calculated performance data for Honduran sawmills is tabulated in Annex 2.

3.4 Case-Study System Configurations

There are several options that need to be evaluated in determining the potential economic viability of wood energy systems for the Honduran wood products industry. Regardless of site-specific considerations, the relative viability of systems designed to produce only the mill energy requirements (energy self-sufficiency) versus systems designed to export electrical energy (off-site energy sales) can be determined from the information available for this study. Also, the

relative impact of the low capital system design versus the energy efficient system design can be established.

figure 3.2

figure 3.3

3.4.1 Mill Energy self-sufficiency

Two options for the design of an energy self-sufficient system include the low capital design and the energy efficient design. As previously stated, preliminary investigations indicate that all of the sawmills in the size range being considered produce more than enough residuals to generate their internal energy requirements using a low capital system design. This being the case, there is no justification for further consideration of an energy efficient design for systems intended only to provide mill energy self-sufficiency, given the additional capital cost of the energy efficient systems. Therefore, the potential economic viability of energy self-sufficient systems can be shown by an economic evaluation of low capital systems designed for both small and large sawmill operations. The cost information that provides the basis for the economic evaluations is summarized in Table 3.1, and is presented in detail in the Annex 2. Figure 3.4 shows the relationship between percent of sawmill wastes required for self-sufficiency and sawmill capacity.

Table 3.1
Summary of Installation & Operating Costs
for Energy Self-Sufficiency Systems

INSTALLATION COSTS

| | LARGE MILL | | SMALL MILL | |
|---|-------------|-----------------|-------------|-----------------|
| Imported equipment | US\$ | 267,075 | US\$ | 211,500 |
| Locally fabricated equipment | Lps | 100,400 | Lps | 99,550 |
| Installation | Lps | 243,950 | Lps | 202,350 |
| Freight, insurance, non-local engineering, supervision, etc. | US\$ | 147,289 | US\$ | 117,467 |
| Import duties and local services | Lps | 279,183 | Lps | 230,174 |
| Total Installed Cost | US\$ | 532,012* | US\$ | 429,358* |

ANNUAL OPERATING & MAINTENANCE COSTS

| | | | | |
|------------------------------------|------------|----------------|------------|---------------|
| Operating Labor | Lps | 65,000 | Lps | 57,500 |
| Operating Supplies | Lps | 20,000 | Lps | 15,000 |
| Maintenance | Lps | 35,000 | Lps | 25,000 |
| Total Annual O & M Cost | Lps | 120,000 | Lps | 97,500 |

* conversion based on US\$ 1.00 = Lps. 5.30

Using approximations from Figure 3.4, note the approximate percentages below for mill sizes considered in this study:

| <u>MILL SIZE</u> | <u>APPROXIMATE % REQUIRED FOR SELF-SUFFICIENCY</u> | <u>APPROXIMATE % AVAILABLE FOR EXPORT POWER GENERATION</u> |
|--------------------|--|--|
| 1.2 Mbf/yr | 100 | 0 |
| "small" (3 Mbf/yr) | 60 | 40 |
| "large" (9 Mbf/yr) | 37 | 63 |

3.4.2 Energy Produced for Off-Site Sales

Because of the assumption that grid connected systems will be tied into a distribution network that can consume all of the excess electricity produced by the generating plant, the selection of the most suitable design for these systems is solely dependent on an evaluation of the value of the excess electricity versus the installed and operating costs of the system. The assumption of unlimited load will not necessarily hold true for systems connected to a micro-grid, but evaluation of potential micro-grid loads is beyond the scope of this study and can only be done on a site-specific basis. The results of this study will provide information on the economic impact of the size of the micro-grid and on the grid development cost that can be incurred without jeopardizing project viability.

Cost information has been developed for both low capital and energy efficient, grid connected system designs for both large and small sawmill operations and is summarized in Tables 3.2 and 3.3 respectively. Detailed cost estimates are presented in Annex 2.

Table 3.2
Summary of Installation & Operating Costs
for Low Capital, Grid-connected Systems

INSTALLATION COSTS

| | LARGE MILL | | SMALL MILL | |
|---|-------------------|-----------------|-------------------|-----------------|
| Imported equipment | US\$ | 398,250 | US\$ | 226,700 |
| Locally fabricated equipment | Lps | 103,100 | Lps | 99,800 |
| Installation | Lps | 345,550 | Lps | 211,050 |
| Freight, insurance, non-local engineering, supervision, etc. | US\$ | 217,796 | US\$ | 125,548 |
| Import duties and local services | Lps | 395,842 | Lps | 243,009 |
| Total Installed Cost | US\$ | 775,384* | US\$ | 456,750* |

ANNUAL OPERATING & MAINTENANCE COSTS

| | | | | |
|------------------------------------|------------|----------------|------------|----------------|
| Operating Labor | Lps | 87,500 | Lps | 65,000 |
| Operating Supplies | Lps | 35,000 | Lps | 17,000 |
| Maintenance | Lps | 42,000 | Lps | 27,000 |
| <hr/> | | | | |
| Total Annual O & M Cost | Lps | 164,500 | Lps | 109,000 |

Table 3.3

**Summary of Installation & Operating Costs
for *Energy Efficient, Grid-connected* Systems**

INSTALLATION COSTS

| | LARGE MILL | | SMALL MILL | |
|---|-------------------|-------------------|-------------------|-----------------|
| Imported equipment | US\$ | 538,150 | US\$ | 303,600 |
| Locally fabricated equipment | Lps | 101,350 | Lps | 98,750 |
| Installation | Lps | 404,300 | Lps | 232,700 |
| Freight, insurance, non-local engineering, supervision, etc. | US\$ | 291,458 | US\$ | 165,735 |
| Import duties and local services | Lps | 507,950 | Lps | 302,313 |
| <hr/> | | | | |
| Total Installed Cost | US\$ | 1,020,853* | US\$ | 588,913* |

ANNUAL OPERATING & MAINTENANCE COSTS

| | | | | |
|------------------------------------|------------|----------------|------------|----------------|
| Operating Labor | Lps | 87,500 | Lps | 65,000 |
| Operating Supplies | Lps | 28,000 | Lps | 14,000 |
| Maintenance | Lps | 52,000 | Lps | 32,000 |
| <hr/> | | | | |
| Total Annual O & M Cost | Lps | 167,500 | Lps | 111,000 |

* conversion based on US\$ 1.00 = Lps. 5.30

The relationship between electrical generation and sawmill capacity is shown for both the *low capital system* and the *energy efficient system* in Figure 3.5. This figure illustrates the dramatic increases in output between the low capital and energy efficient systems.

3.5 Densification of Excess Wastes

Densification of wood wastes is a well-known technology and is widely used in the northwestern United States and northern Europe for both domestic heating markets and industrial energy applications. Densification of wood wastes typically entails the manufacture of pellets or briquettes through an extrusion process which requires high pressures and temperatures (commonly a result of the mechanically-based extrusion process). In most cases, binding agents are not required. Many densified fuels can be made into charcoal, which increases combustion

efficiency and reduces transportation costs, but consumes a large amount of the fuel's heat energy in the carbonization process. Densified fuels can be made from sawdust or a mixture of pulverized hogfuel and sawdust. Pellet or briquette sizes typically range from 0.25" to over 3" in diameter.

Densification technology is certainly an option that should be considered for mills that do not have access to a grid for sale of excess electricity, and may represent a more attractive investment for some mills that do have grid access. The economics of investment in such equipment depend on numerous considerations and should be assessed on a case-by-case basis.

The Yodeco sawmill at Yoro is currently installing wood densification equipment and will begin producing briquettes in May or June of this year. Site specific studies in Honduras should consider the results of the Yodeco project to help evaluate the feasibility of densification.

3.6 Summary

There are no significant technical constraints to the installation of wood energy systems in Honduras to use sawmill wastes for the production of internal energy needs and exported electricity. The devices that appear to be most practical for these applications are the fire-tube type boilers and single stage steam turbine generators in systems that require no additional fuel preparation and operate without sophisticated auxiliaries and control systems. This technology is similar to that used in sawmills in the United States in the first half of this century, and ample information is available on the design parameters that should be considered.

If the generating systems are designed to produce only the internal energy requirements of the mills included in the scope of this study, it appears that approximately 10 million kWh per year of electricity currently supplied from the grid or by diesel generators could be displaced. If all of the available residuals were utilized in systems incorporating the "energy efficient" design, approximately 53.7 million kWh of electricity could be produced for sales to national, local or micro-grids.

The use of waste-wood energy systems for kiln drying represents a significant benefit to Honduran sawmills. The case-study systems discussed herein provide enough steam and electricity for drying 25 percent of the mill's primary lumber production. It has been suggested that for some Honduran sawmills, as much as 70 percent of the lumber could be dried with significant benefit to the mill. Investigations of this issue should be undertaken in all site-specific feasibility studies.

Table 3.4 presents a summary of operating characteristics and projected installation and operations & maintenance costs for the six case study systems. It should be noted that the systems designed for off-site sales have been designed to generate approximately 70% of the exported electricity during the peak rate periods (13 hours/day, as established by ENEE); the balance of the exported electricity is produced during off-peak periods. If the systems were designed and operated to generate a constant output, the size of the turbine generator could be reduced, thereby reducing the equipment costs. The potential exportable electricity on a constant basis from large and small representative sawmills, using the energy-efficient technologies

described herein, would be approximately 455 kW and 140 kW, respectively (@ 300 days per year).

The determination of generator output (constant vs. varying levels of output corresponding to peak and off-peak grid demands), which in turn affects system design and capital cost, should be determined in an economic analysis of the revenues from peak vs. off-peak sales and the respective system costs, which must be undertaken on a site-specific basis.

Densification of excess wood wastes for off-site sales to domestic or industrial markets should be considered at Honduran sawmills, particularly those that do not have access to a grid for sale of excess electricity. Investments in such equipment should be assessed on a case-by-case basis. The Yodeco sawmill at Yoro is currently installing wood densification equipment; results of their project should be of interest to other Honduran sawmills.

table 3.4

4. Economic & Financial Considerations

4.1 General Comments

The wood-products industry in Honduras is the country's largest non-agricultural earner of foreign exchange. Investments in this sector are therefore important to the national economy. However, due to the uncertainty of the long-term availability of raw materials, investments in the Honduran wood-products industry must be carefully evaluated. (Chronowski, 1985; UNDP, 1985) Timber resources are being managed by COHDEFOR to assure a fairly constant supply of raw material to sawmills over the next fifteen years or so. Beyond that, little is being done to assure or assist in the process of reforestation. Indeed the present system provides important disincentives to the growing of new trees. Many mills are unable to operate at their full production capacity because of tight regulation of the raw material supply. The long-term outlook for the industry is very uncertain. Nonetheless, *the economic feasibility for investment in wood-energy systems for Honduran sawmills appears attractive, since the rates of return appear acceptable and payback periods are well within the period of reasonably assured timber supplies.*

The majority of the sawmills in Honduras are located in remote rural areas. When most of these sawmills were built utility electrical service was not available, so all of the sawmills' energy needs had to be produced on-site. The lowest capital-cost alternative, and the one chosen by most mill owners, is the industrial diesel-engine generator. The sawmills themselves are designed for minimal power requirements, so the amount of fuel that has to be trucked in is not excessive. Diesel engines are relatively easy to operate, and most sites have multiple engines to increase the electrical system's reliability and availability.

It has been a long-standing policy of the Honduran Government to subsidize the price of diesel fuel to all sectors of the economy. During the project team's site visit to Honduras (September 1990), diesel fuel was priced at Lps. 3.99 per gallon (US\$ 0.75/gal), which compared with Lps. 6.25 per gallon (US\$ 1.18/gal) for regular gasoline⁶. The subsidy covers all diesel fuel sold in the country, including the fuel purchased by the sawmill industry. Thus, the subsidy keeps the cost of energy generation at sawmills below market levels. The subsidization of diesel fuel has

⁶The current (March 1991) price of regular gasoline is 8.63 Lps./gal, while the current price of diesel fuel in Honduras is 6.94 Lps./gal, which is the price used for analysis in this study. The level of subsidy given to diesel has decreased, and the government's recently announced policy of fuel price stabilization will preserve the current status quo for the foreseeable future.

important implications for decisions about whether to install waste-wood energy systems at sawmills since the cost of energy derived from diesel fuel is lower than world market prices.

4.2 Case Study Analyses

A preliminary economic analysis was performed using a ten-year pro forma cash flow model for each of the six representative case-study system configurations as described in Table 3.4, and the common set of financial assumptions shown in Table 4.1. Table 4.2 shows the results of the financial analyses of the six representative systems. Details of the full pro formas for each of the six system configurations are set forth in Annex 4.

Table 4.1
Common Assumptions Used for Financial Analysis

| | |
|---------------------------------------|---|
| Annual Energy System Operating Hours: | 24 hours/day, 300 days/year |
| | includes all hours during which boiler is operated |
| Annual Sawmill Operating Hours: | 8 hours/day, 250 days/year |
| | typical total hours of sawmill operations in Honduras |
| Electricity Sales Price: | 0.31 Lps/kWh, 1992, all hours |
| | = based on 0.248 Lps/kWh, ENNE's cost of service in 9/90, plus |
| | 20% annual inflation applied over a 15-month period to arrive at a 1992 price |
| Diesel Fuel Price: | 8.33 Lps/gallon, 1992 |
| | = 6.94 Lps/gallon in 1991; incorporates 20% inflation to 1992 |
| Diesel O&M and Depreciation: | 75,000 Lps/year — small mill site |
| | conservative estimate based on 2 diesel engines, 250 kW total capacity |
| | 85,000 Lps/year — large mill site |
| | conservative estimate based on 2 diesel engines, 400 kW total capacity |
| Currency Exchange Rate: | 5.3 Lps/US\$, 1991 |
| | current official exchange rate (3/91) |
| Honduran Inflation Rate: | 20%/year, 1991 – 2002 |
| | assumption consistent with USAID/Honduras' economic officer's opinion |
| Honduran Energy Price Inflation Rate: | 20%/year, 1991 – 2002 |
| | assumed to be same as general inflation rate |
| Currency devaluation Rate: | 10%/year, 1991 – 2002 |
| | assumption consistent with USAID/Honduras' economic officer's opinion |
| Debt amount: | 80% of total loaded capital cost |
| | assumption regarding financial structure |
| Debt terms: | 5 year amortization, 1 year grace period |
| | assumption based on discussions with lenders and agents |
| Lempira Debt Rate: | 28% |
| | assumption consistent with USAID/Honduras' economic officer's opinion |
| Dollar Debt Rate: | 12% |
| | assumption based on discussions with lenders and agents |
| Project Construction Period: | 12 months |
| | assumption based on engineering design in §3 |

Discount Rate: 15%
assumption used for net present value calculations

Table 4.2

Note that the analyses presented in this overview report are preliminary. While these calculations are considered satisfactory indicators of the investment returns associated with the various case study configurations, site-specific studies will require more in-depth assessment of many of the common assumptions on which these calculations are based. In cases where general assumptions or incomplete information had to be used in these analyses, our approach has been conservative.

For example, our estimates of capital costs may be high because we have assumed that most of the major pieces of equipment have to be imported. In fact, some of the equipment could be purchased in used condition, or may be available domestically at considerable savings. Another example of conservatism is that although we have designed the systems to provide steam to kiln dry 25% of the lumber output of the mill, we are not crediting the systems with any financial benefit associated with the higher value of the dried lumber products (nor incorporating the costs associated with the kiln drying systems). Overall, these preliminary analyses are considered conservative, and site-specific feasibility studies should result in even more attractive investment scenarios.

4.2.1 Low capital cost, mill energy self-sufficiency

We have conducted indicative financial analyses for self-sufficiency energy systems at the large and small representative sawmill sites, based on the low capital cost, low efficiency design case, and the common base-case financial assumptions. The calculated internal rate of return (IRR) for the large and small system configurations, respectively, are 21.7% and 16.7%; simple payback periods are 6.2 and 5.7 years. The base case self-sufficiency energy systems thus have financial performances that make them acceptable candidates for investment. Developments in several areas, especially capital cost reduction associated with the purchase of used equipment, for example, could make these types of systems more attractive investments. The larger system has significant economies of scale in comparison with the smaller system, a factor that holds for all system configurations studied. However, for the energy self-sufficiency system configurations, the larger systems dispose of a smaller percentage of the total sawmill wastes than the smaller systems, and thus provide less of a solution to the mill's waste disposal problems. For self-sufficiency systems, densification may be an attractive option for disposing of excess wastes.

4.2.2 Low capital cost, off-site energy sales

Wood-energy systems using the same technology as in the case for the mill self-sufficiency configurations, but sized to consume the entire available sawmill waste supply, can be designed to provide energy for both sawmill energy requirements and for off-site energy users. Energy systems at sawmills that are able to generate and sell their excess electricity have distinct economic advantages over installations that are only designed to provide energy for sawmill self-sufficiency. The revenues received from the sales of excess electricity more than compensate the

higher capital costs and slightly higher operating costs of the systems, and these systems provide the additional benefit of complete waste disposal.

The results of the analysis of the large and small systems in the low capital cost, off-site energy sales configuration show an IRR of 53.4% and 32.2%, respectively. Simple payback periods are 4.0 and 5.0 years. The systems easily meet normal minimal investment criteria, and represent potentially very attractive investments for sawmills that expect to operate at least through the end of the decade.

4.2.3 Energy efficient design, off-site energy sales

Sawmills with access to sufficient markets for surplus energy sales can consider investing in more efficient but costly generating equipment than the low capital-cost technology considered above. The energy efficient technology considered in this study produces almost twice as much electricity from the same amount of waste wood as the low capital-cost technology. Although the capital costs for this alternative are higher than for the low capital-cost technology, the annual operating costs and skills required are fairly comparable, and the additional capital cost is more than compensated by the additional revenues earned.

The projected financial returns for these systems are extremely attractive, ranging from over 40% IRR for the smaller system to over 75% IRR for the larger system. Simple payback periods are roughly 3.4 and 4.4 years for the large and small systems, respectively. These results are also very positive in that such configurations could maximize potential off-site electricity sales. This would result in substantial contributions to the national electrical picture from the forest products industry, a concept which has received strong interest from ENEE.

4.3 Sensitivity Analyses

We have run a series of sensitivity studies on the economic analyses discussed above. Our attempt has been to examine each of the major assumptions and variables that make up the base-case configurations, in order to gauge the sensitivity and robustness of the results. The purpose of the sensitivity analyses is to determine how great a change is necessary in each base-case variable in order to cause the project IRR to fall to 15%, which is considered a minimal return for a successful investment. Five key variables were selected for analysis:

- o project capital cost
- o project operating costs
- o overall inflation rate in Honduras (in Lempira)
- o rate of currency devaluation (Lps : US\$)
- o rate of energy price inflation in Honduras (%/year)

Table 4.3 summarizes the results of the sensitivity analyses of these five variables on the six base-case system configurations. The first row of data repeats the base case IRRs from Table 4.2. The first column of data shows the base-case values of the sensitivity variables. The body of the table shows the values of the variables that cause the projects' IRR to fall to 15%, in each case keeping all other variables at base-case levels.

table 4.3

The financial performances are more sensitive to increases in capital costs than to increases in operating costs. For example, the large sawmill, low-capital self-sufficiency configuration could absorb an increase in capital cost of 19% before falling to a 15% IRR, while an increase of 36% in operating costs would be necessary to cause the same fall in IRR. The self-sufficiency configurations, particularly at the lower end of the size range studies, are very sensitive to changes in these variables, whereas all of the configurations that include off-site energy sales could absorb large increases in capital costs and operating costs before the IRRs fall to 15%.

In the base-case assumptions shown in Table 4.1, general inflation in Honduras is assumed to be 20% per year, with energy inflation at the same 20% level, and devaluation of the Lempira relative to the dollar at 10% per year. Predicting these variables into the future is extremely difficult, and the results of the financial analyses are quite sensitive to these predictions. High general inflation in Honduras actually improves the financial performance of the energy investments, by increasing future revenues and savings. Inflation in Honduras has been on the low side relative to much of Latin America, but reached 35% in 1990 when major economic and currency reforms were implemented. Most analysts do not expect the government to be able to bring the annual inflation rate down below 20% in the foreseeable future, with 15% often listed as the best that could be achieved. The system configurations that include off-site energy sales remain attractive even with domestic inflation rates below 10%.

The rate of devaluation of the Lempira relative to the dollar is also a key financial variable, and one that may be even more difficult to predict than the general inflation rate. Until March 1990 the exchange rate was fixed for a long period of time at Lps. 2.00 = US\$ 1.00. Current policy seems to be to let the Lempira exchange at close to its market price, although some level of control is still in effect. Assuming a 20% inflation rate in Honduras, and a 5% inflation rate for the dollar, an exactly correcting devaluation rate would be 15%. In fact, most analysts expect the rate of devaluation to be lower than this, and we have chosen 10% for our base case. For system configurations with off-site energy sales, only devaluation rates in excess of the assumed general inflation rate (20%) would have serious negative impacts on investment attractiveness.

The rate of inflation in energy prices in Honduras can be very different than the overall rate of general inflation, although for the base case we have assumed it to be the same. Diesel fuel prices increased by about 75% in the last quarter of 1990 in response to the Persian Gulf situation. With recent successful roll-back and stabilization of world oil prices, the Honduran Government announced a policy of using special taxes to stabilize fuel prices at their level of March 1991. Together, these factors make a substantial risk that Honduran fuel prices could increase at rates below general inflation, at least over the short term.

4.4 Other Financial Considerations

With the recent closing of the Corfino plant, all operating sawmills in Honduras are privately owned. While government funds are not required for investments in wood-energy systems, government support is considered very important, and is probably essential in order for sawmills to sell excess electricity to ENEE. The utility's attitude to date has been encouraging. ENEE has indicated that it would be willing to purchase all excess electricity that could be generated by the forest/sawmill sector; in fact, it would like to purchase as much as could be made available. Further, ENEE has expressed support of the concept of establishing rural electric cooperatives, which could play a key role in establishing demands for excess electricity available from remote, off-grid sawmills for nearby villages. Although this study has not investigated power purchase agreements between private generators and ENEE, details of such agreements should be established prior to investment in equipment intended to generate excess electricity for sale to national, local, or micro-grids.

The availability of capital for investment purposes is a crucial factor for Honduran sawmill owners. Interest rates from Honduran banks for private loans of the nature required for equipment purchases have typically been in the range of 15% to 20%, but loans have been extremely limited and difficult to obtain. Recent liberalization of government policies regarding consumer interest rates may make funds more available, but rates have risen to the mid 20s and are expected to approach 30%. Possible external (i.e. international) funding sources include loans from bilateral aid sources (either direct or through local banks), multilateral lending institutions such as the Inter-American Development Bank (through local banks), and other, private sources such as venture capital firms. Regarding bilateral sources, USAID has a component of the funding for the PDF project that is intended to support capital investments specifically for improvements in Honduran sawmill operations, which presumably could include wood-energy systems. Such funding would be through local banks. However, at the time of this study, establishment of the mechanisms for such investment support was not complete. Regarding private external sources, the single largest consideration will be repatriation of capital. Those sawmills with export activities, and therefore access to hard currencies, will find it easier to attract such capital. Governmental guarantees in this area would be very helpful.

4.5 Summary

All of the mills in Honduras that exceed approximately 1 million board-feet of annual lumber production also produce enough waste wood to provide 100% of their own energy needs. The larger the individual mill, the more excess waste is available, both in absolute terms (total tons) and in relative terms (as a percentage of the total mill waste output). These wastes could be used to produce energy products for off-site sales, assuming there is a market for the excess power. Excess energy sales enhance the economic performance of an investment in a wood-energy system, and encourage the use of more efficient energy conversion technology, with greater national domestic energy production and pollution abatement benefits.

Using the conservative base-case assumptions, the mill energy self-sufficiency systems alone meet or exceed acceptable financial performance levels. When the additional benefits available from self-sufficiency energy systems are factored in, such as the ability to run dry kilns and to do more secondary product manufacturing, these types of systems look more attractive in the context of the entire sawmill operation.

Those systems that could engage in off-site energy sales are even more financially attractive, particularly if additional capital is invested in order to maximize system energy generation efficiency. Larger mills can take advantage of considerable economies of scale in comparison with smaller mills in the size range considered in this study, regardless of system configuration.

For the large and small *energy-efficient, grid-connected* case studies, the respective internal rates of return exceed 70% and 40%, with simple payback periods of 3.4 and 4.4 years. For the large and small *low-capital, grid-connected* case studies, the respective internal rates of return are 53.4% and 32.2%, with simple payback periods of 4.0 and 5.0 years. For the large and small *low-capital, self-sufficient* case studies, the respective internal rates of return are 21.7% and 16.7%, with simple payback periods of 5.7 and 6.2 years.

5. Conclusions and Recommendations

Waste-wood-fired energy systems installed at sawmills offer many important benefits for Honduras, including increased national energy independence, increased rural employment opportunities and income, and decreased environmental degradation associated with sawmill wastes. The results of this overview assessment indicate three important points:

- o There are no significant technical constraints to the use of wood energy systems in Honduras.
- o Investments in wood energy systems in Honduras would meet or exceed reasonable investment performance criteria. Such investments at larger sawmills and sawmills that have markets for off-site sales of surplus energy products would be especially attractive.
- o Waste-wood-fired energy systems could significantly increase the national energy supply in Honduras, while substantially reducing waste disposal problems.

5.1 Energy Potential of the Honduran Forest Industry

If all of the sawmills in Honduras in the size range considered in this study were to achieve only energy self-sufficiency with waste-wood energy systems, the potential energy savings to the country would be greater than 1 million gallons of diesel fuel per year. Such systems would provide nearly 10 million kWh/yr of electricity to the sawmill industry, and enough steam to kiln dry approximately 25 percent of the nation's lumber output, thus resulting in higher-value products.

Energy self-sufficient systems, however, would provide only a partial solution to the problem of waste disposal at Honduran sawmills. If all of the mills were to build self-sufficient energy systems, there would still exist over 150,000 tonnes per year of excess sawmill wastes nationwide (for large mills, less than half of the available wastes would be disposed of by energy self-sufficient systems).

We can calculate the theoretical amount of *excess* power that could be generated from sawmill wastes in Honduras, but it is difficult to estimate the amount of actual, saleable excess power from sawmill wastes because of the need for grid access or other markets for utilization of the surplus energy. For the group of sawmills under consideration in this study, use of the low-capital-cost design configuration would allow the production of more than 20 million kWh of export power (in addition to the ~10 million kWh of power produced for sawmill consumption),

while use of the energy-efficient design configuration would allow the production of nearly 53.7 million kWh of export power for off-site sales (in addition to mill energy self-sufficiency).

Note that our calculations of excess power potentially available from Honduran sawmills do not reflect the enormous potential of power generation from forest residues. The social, silvicultural, and economic benefits that could be derived from collection and combustion of forest residues in Honduras warrant further investigation of this option.

5.2 Technical Conclusions

There are no significant technical constraints to the installation of wood energy systems in Honduras to use sawmill wastes for the production of internal energy needs and exported electricity. The technology that appears to be most practical for these applications is the utilization of fire-tube type boilers and single stage steam turbine generators in systems that have been designed to require no additional fuel preparation and operate without sophisticated auxiliaries and control systems. This technology is similar to that used in sawmills in the United States in the first half of this century, and ample information is available on the design parameters that should be considered. In fact, such technology is already in use at a few sites in Honduras.

For self-sufficiency applications, the low-capital system design shown in Figure 3.2 represents the least-cost alternative. For maximum power generation, with the objective of selling excess power, the more energy-efficient system in Figure 3.3 is recommended. Note that equipment is available that is more than twice as efficient, in terms of kilowatts of electricity produced per unit of fuel (sawmill wastes), than the system referred to in this study as "energy-efficient." Such systems are much more expensive, but should be considered during site-specific analyses of large sawmills that have the potential to sell as much excess electricity as could be generated.

The use of waste-wood energy systems for kiln drying represents a significant additional benefit to Honduran sawmills. We have designed our case-study energy systems to provide enough steam and electricity for drying 25 percent of the mill's primary lumber production. It has been suggested that for some Honduran sawmills, as much as 70 percent of the lumber could be dried with significant benefit to the mill. Investigations of this issue should be undertaken in all site-specific feasibility studies. Components of this issue that will have to be considered include the costs of kiln drying and, possibly, surfacing (including capital and operating costs for each), as well as potentially enhanced revenues resulting from increased product values and reduced freight costs.

An alternative to production of steam and/or electricity from surplus sawmill wastes is to densify such wastes into pellets or briquettes for off-site markets, such as energy-intensive industrial operations or domestic cooking and heating. Densified fuels are far more economical to transport than loose sawmill wastes, and can be used relatively easily as a fuel source. As noted in §1.4.2 and §3.5, the Yodeco sawmill in Yoro intends to densify some of its excess sawmill wastes, and to begin identifying markets for such fuel. Densification of excess wastes may be

economically attractive to Honduran sawmills that do not have access to national, local, or micro-grids. Additional energy available on-site from waste-wood energy systems as described herein could promote alternative usage of excess sawmill wastes such as densification.

5.3 Financial Conclusions

Investments in wood-energy systems meet or exceed acceptable financial performance levels. Those systems able to sell excess electricity to national-, local-, or micro-grids show higher returns than systems designed only for self-sufficiency. Larger systems show higher economic returns than smaller systems. Increased investment returns could result from purchase of used equipment, or perhaps from purchase of locally-fabricated equipment. Such investments are also attractive in the context of improvements in overall sawmill operations, if combined with kiln drying operations and/or increased secondary product manufacturing. Further, we have not analyzed the potential positive returns that might result from densification and off-site sales of *excess* sawmill wastes, nor have we incorporated any costs associated with anticipated future waste disposal requirements.

Investments in the energy-efficient systems are even more attractive, provided that all excess power can be sold for prices near Lps. 0.31 per kilowatt-hour in 1992 (US\$ 0.052/kWh). (Note: although this rate might be adjusted upward slightly for peak periods, the base price is considered low, relative to international rates. This rate is based on ENEE's current power generation costs, which are based almost entirely on hydro, and do not show much sensitivity to season or time-of-day. ENEE's peak power demand is expected to exceed capacity by about 1992 or 1993. After that time, peak power generation costs will no longer be based on low-cost hydro. The current proxy used by ENEE for peak power generation over the last half of this decade is a 50 MW, oil-fired peaking plant that is under consideration for development by the utility. We have not included any consideration for the likely corresponding revenue increases available from peak power sales to the utility in our analyses.)

For the large and small *energy-efficient, grid-connected* case studies, the respective internal rates of return exceed 70% and 40%, with simple payback periods of 3.4 and 4.4 years (assuming 1 year grace periods on loans). For the large and small *low-capital, grid-connected* case studies, the respective internal rates of return are 53.4% and 32.2%, with simple payback periods of 4.0 and 5.0 years. For the large and small *low-capital, self-sufficient* case studies, the respective internal rates of return are 21.7% and 16.7%, with simple payback periods of 5.7 and 6.2 years.

5.4 Overall Conclusions

This study reveals the overall technical and economic feasibility of wood energy systems in Honduras. The results of this overview assessment are sufficiently attractive to warrant follow-up activities that will investigate site-specific opportunities and stimulate investments in wood energy systems throughout Honduras. Several possible follow-up activities exist:

a) Site-specific analysis of a Honduran sawmill *with* grid access

A site-specific feasibility study could be conducted at a Honduran sawmill that has access to an existing grid. The study would undertake a detailed analysis of the technical and economic feasibility of a wood-energy system designed for maximum energy production, with sales of all excess electricity to the grid. Such a study could also compare the feasibility of densifying excess sawmill wastes to sale of excess electricity to the grid.

b) Site-specific analysis of a Honduran sawmill *without* grid access

A site-specific feasibility study could be conducted at a Honduran Sawmill that does not have access to an existing grid. The study would undertake a detailed analysis of the technical and economic feasibility of a wood-energy system designed to generate only enough energy required for self-sufficiency. Such a study could also investigate the feasibility of densifying excess sawmill wastes as part of the energy system.

c) Site-specific analysis of a sawmill without grid access, but with the probability of establishment of a local or micro-grid market

One concept is to identify a situation in Honduras where remotely-located sawmills do not have access to an existing grid but are located near existing villages that do not have electric utility service. If the existing villages are large enough and have the purchasing power, then it could be possible to match the potential supply and demand, i.e. for the village to establish its own grid and the sawmill(s) to generate excess electricity for sale to that grid. Such a project would have numerous benefits, including rural electrification, increased revenues for the sawmill(s), and consumption of the excess sawmill wastes.

One possibility for such an opportunity identified by the study team was the village of La Unión, in Olancho. Two sawmills are located near La Unión: San José (8.9 Mbf, 1989; within 8 kilometers), and Honduply (a relatively new mill, with an expected production of approximately 3.0 Mbf/year; within 3 kilometers). However, after consultation with representatives from the CARES project (see §1.4.2), it was determined that the village does not currently have enough population or purchasing power to justify pursuing this concept at this time. Nonetheless, the concept remains viable, and efforts should be continued to identify other sites with the possibility of matching potential energy supplies with potential energy demands.

d) Site-specific analysis of an *independent* power station using sawmill wastes (and, possibly, forest residues) for fuel

In this type of project, the generating plant would purchase wastes from various sawmills and sell electricity to the grid. Alternatively, some of the facility's electricity and/or steam could also be sold to adjacent sawmills or other industrial users. Given the high costs of

transporting wood wastes, an independent power project probably would need to be located close to a group of sawmills.

The possibility for such a facility exists in the Talanga/Guaimaca area, which is approximately 40–70 kilometers east of Tegucigalpa. There are numerous sawmills in this area, all located on a high-quality and relatively straight and level paved road. In addition, the area has full transmission access to the national grid.

Note that there are numerous independent power generating facilities in the United States and other developed countries that use wastes from the forest products industry for generating power for sale to the national grid(s). However, the BEST project has not identified any such facilities in developing countries. Thus, such a project in Honduras could be the first wood-waste-fired facility to sell a significant amount of electricity to a national grid in a developing country.

5.5 Recommendations

The results of this overview study were reviewed and discussed with representatives from COHDEFOR, ENEE, and USAID in March 1991. During the discussions, it was agreed that, based on this study, the BEST project will undertake site-specific feasibility studies regarding investments in wood-energy systems in Honduras. Two activities have been identified:

- o Investigate, in detail, the feasibility of investing in a wood energy system at a specific site. The site should be representative of other sawmills in Honduras so that the results of the study, which will be publicly available, can be used by other sawmills for analyzing their potential wood energy opportunities. The overall objective is to stimulate investments in wood energy systems throughout Honduras. Since this study shows investment in wood energy systems by larger sawmills to be more economically attractive than at smaller mills, investigation of a smaller mill would be effective as a representative study. The site chosen for this study, based on its representative size and configuration and on the serious interest indicated by its owner, is the Teupasenti sawmill in El Paraiso.
- o Investigate the feasibility of an independent, centrally located power station using sawmill wastes and/or forestry residues from numerous sawmills. Such a project could result in a substantial amount of power sold to ENEE, as well as provide an acceptable method of disposing of large quantities of sawmill wastes. The target area chosen for this study is the Talanga/Guaimaca area. The study will include identification of a host site (possibly at or adjacent to an existing facility, or as a separate system).

Both studies are expected to begin in May or June 1991. The BEST study team for the site-specific activities will continue to coordinate all activities with—and seek support from—COHDEFOR, ENEE, and USAID/Honduras.

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The Office of Energy

The Agency for International Development's Office of Energy plays an increasingly important role in providing innovative approaches to solving the continuing energy crisis in developing countries. Three problems drive the Office's assistance programs: high rates of energy and economic growth accompanied by a lack of energy, especially power in rural areas; severe financial problems, including a lack of investment capital, especially in the electricity sector; and growing energy-related environmental threats, including global climate change, acid rain, and urban air pollution.

To address these problems, the Office of Energy leverages financial resources of multilateral development banks such as The World Bank and the Inter-American Development Bank, the private sector, and bilateral donors to increase energy efficiency and expand energy supplies, enhance the role of private power, and implement novel approaches through research, adaptation, and innovation. These approaches include improving power sector investment planning ("least-cost" planning) and encouraging the application of cleaner technologies that use both conventional fossil fuels and renewable energy sources. Promotion of greater private sector participation in the power sector and a wide-ranging training program also help to build the institutional infrastructure necessary to sustain cost-effective, reliable, and environmentally-sound energy systems integral to broad-based economic growth.

Much of the Office's strategic focus has anticipated and supports recently-enacted congressional legislation directing the Office and A.I.D. to undertake a "Global Warming Initiative" to mitigate the increasing contribution of key developing countries to greenhouse gas emissions. This strategy includes expanding least-cost planning activities to incorporate additional countries and environmental concerns, increasing support for feasibility studies in renewable and cleaner fossil energy technologies that focus on site-specific commercial applications, launching a multilateral global efficiency initiative, and improving the training of host country nationals and overseas A.I.D. staff in areas of energy that can help to reduce expected global warming and other environmental problems.

To pursue these activities, the Office of Energy implements the following seven projects: (1) The Energy Policy Development and Conservation Project (EPDAC); (2) The Biomass Energy Systems and Technology Project (BEST); (3) The Renewable Energy Applications and Training Project (REAT); (4) The Private Sector Energy Development Project (PSED); (5) The Energy Training Project (ETP); (6) The Conventional Energy Technical Assistance Project (CETA); and (7) its follow-on Energy Technology Innovation Project (ETIP).

The Office of Energy helps set energy policy direction for the Agency, making its projects available to meet generic needs (such as training), and responding to short-term needs of A.I.D.'s field offices in assisted countries.

Further information regarding the Office of Energy's projects and activities is available in our Program Plan, which can be requested by contacting:

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ANNEX 2

**Preliminary Expected Energy Generation Performance Data
for Honduran Sawmills**

List of Spreadsheets Included

- Part A: Expected Performance of Sawmills Operating with System Designed for SELF-SUFFICIENCY, *Low Capital System Design*
- Part B: Expected Performance of Sawmills Operating with System Designed for SELF-SUFFICIENCY, *Energy Efficient System Design*
- Part C: Expected Performance of Sawmills Operating with System Designed for GRID CONNECTION, *Low Capital System Design*
- Part D: Expected Performance of Sawmills Operating with System Designed for GRID CONNECTION, *Energy Efficient System Design*

ANNEX 3

Detailed Engineering Cost Calculations

List of Spreadsheets Included

| Part | Cost Estimate | System Design Basis | Sawmill Size |
|------|--------------------------|----------------------------------|--------------|
| A | installation | low capital, self-sufficiency | large |
| B | operations & maintenance | low capital, self-sufficiency | large |
| C | installation | low capital, self-sufficiency | small |
| D | operations & maintenance | low capital, self-sufficiency | small |
| E | installation | low capital, grid-connected | large |
| F | operations & maintenance | low capital, grid-connected | large |
| G | installation | low capital, grid-connected | small |
| H | operations & maintenance | low capital, grid-connected | small |
| I | installation | energy-efficient, grid-connected | large |
| J | operations & maintenance | energy-efficient, grid-connected | large |
| K | installation | energy-efficient, grid-connected | small |
| L | operations & maintenance | energy-efficient, grid-connected | small |